The Relationship of STEP and CAD Model Quality

Removing a Significant Barrier to the Production Use of STEP

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- Engineering focus: discrete part manufacturing
- Customer base: automotive, aerospace, defense, and consumer goods
- Engineering software development and consulting for 15 years
- Based in Cincinnati, offices worldwide
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Personal Experience with Model Quality

- Model quality research, consulting and software development for past 5 years
- Lead technical consultant for model quality projects:
  - Boeing, AlliedSignal (Honeywell), Pratt & Whitney, Lockheed Martin, NASA, Sandia
  - Ford, DaimlerChrysler, Delphi Automotive, Freightliner, Nissan, Toyota, Mitsubishi, Xerox, Gillette
  - PDES, Inc., ProSTEP, VDA, JAMA, AUSAP
- "Father of CAD/IQ" (commercial ITI product)
- Just beginning to fully understand CAD model quality

Presentation Objective

- Teach vs. entertain or sell
- Share concrete, technical results of production, model quality projects
- Build understanding of the importance of high-quality CAD models to the production use of STEP

Definition of “CAD Model Quality”

- Applies to product shape (topology and geometry)
  - Solid
  - Shell
  - Trimmed surfaces
- Correct (topology structure)
- Accurate (geometric representation)
- Realistic (feature interactions)

Out of Scope for this Presentation

- "Product Model Quality"
  - Assembly structure
  - Versioning
  - Modeling technique
  - Design intent
  - All non-geometric information
- "CAD Software Quality"
  - CAD modeling systems
  - STEP translators

Relationship of Model Quality to STEP

- Good news
  - Most commercial translators are robust enough to handle a wide range of production models
  - STEP translator vendors are working cooperatively (STEPnet, CAx Implementers Forum)
  - Translator best practices are available on-line:
    - » www.cax-if.org/bestprac/practice.html
    - » public.prostep.de/BP
- Bad news
  - **Poor model quality remains one of the major barriers to the production use of STEP**

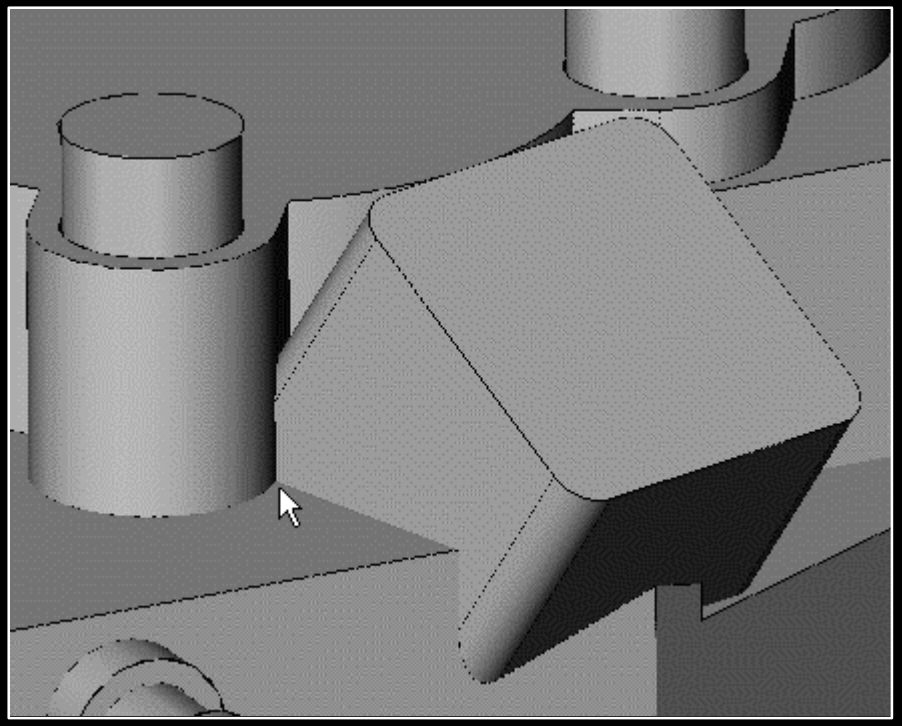
How Poor Model Quality Impacts STEP Real-Time Exchanges

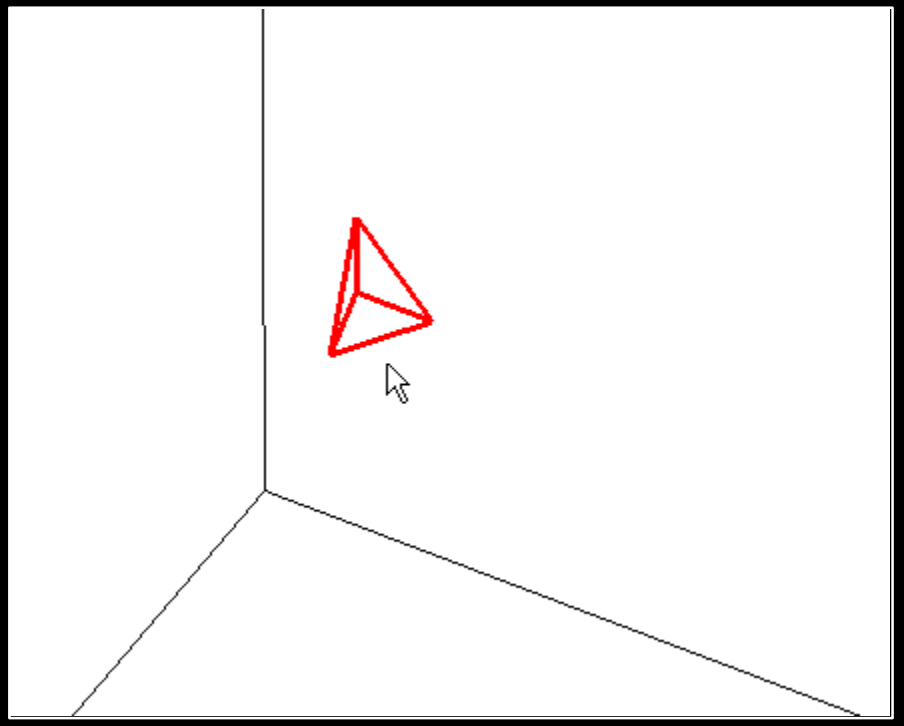
- "Show-stopper" (5-10%)
  - Symptom: Translator crashes on export or import
  - Major cause: Incorrect structure
- "Hindrance" (10-30%)
  - Symptom: Data loss on import (e.g. solid to unsewn surfaces)
  - Major cause: Poor accuracy
- "Sleeper" (30-60%)
  - Symptoms: Data exchange works but analysis, rapid prototyping, or manufacturing fail; ambiguous design intent
  - Major cause: Unrealistic geometry
- Overall: 20% cause 80% of downstream rework

Most Common Structure Problems

- Free edge
- Free vertex
- Over-used edge
- Over-used vertex
- Reversed edge on curve
- Reversed edge in loop
- Reversed face normals
- Solid void

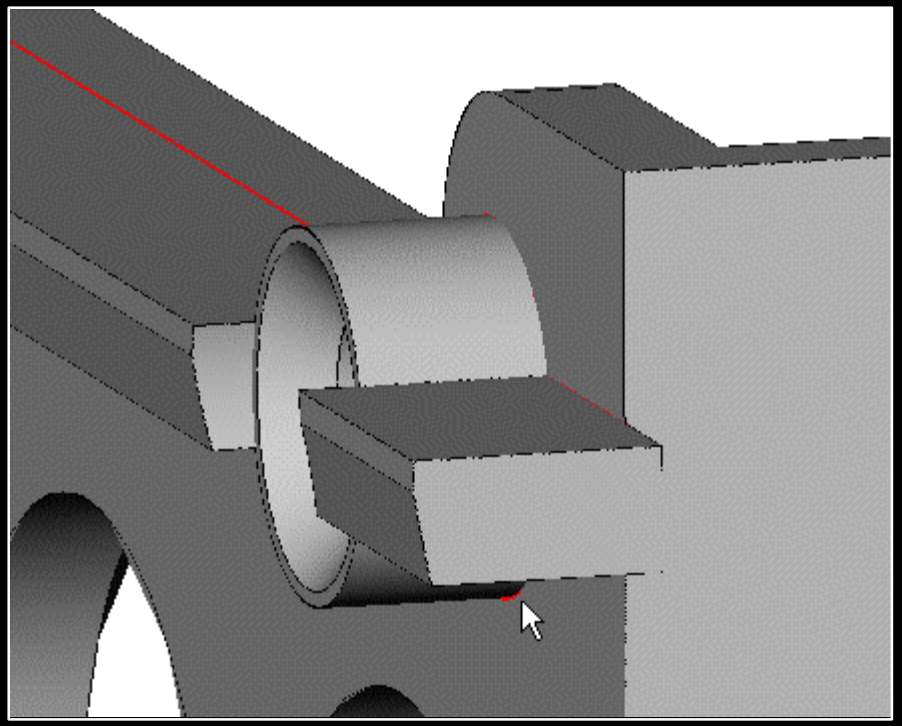
Incorrect Structure Example: Solid Void

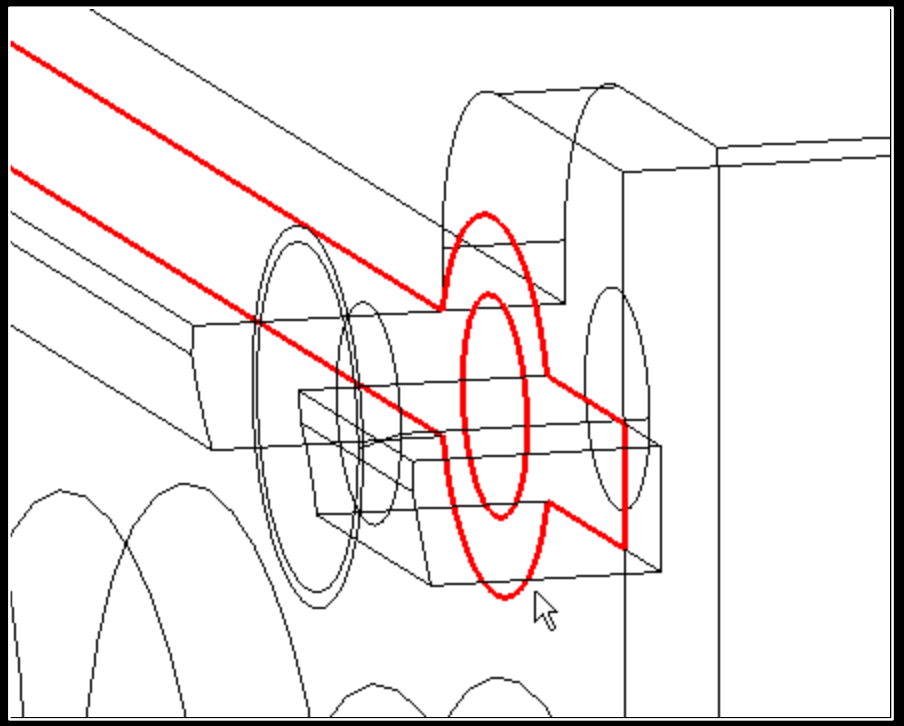




This rounded, square feature does not plunge deep enough into this model. It traps a “pocket of air” in this corner. The faces of this void have areas between 0.0062 and 0.013 mm^2.

Incorrect Structure Example: Interior Face



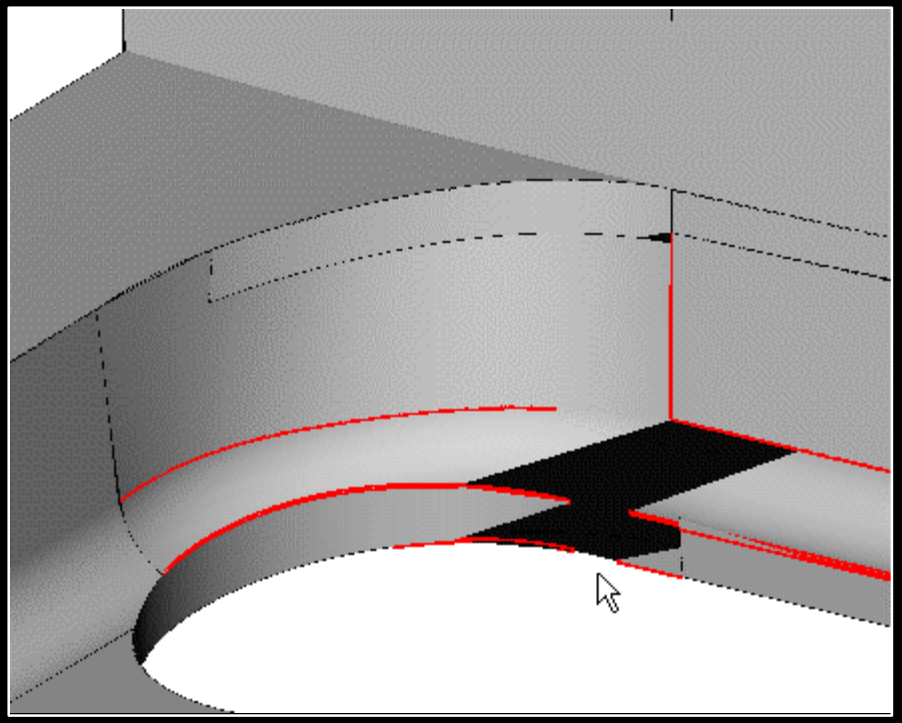


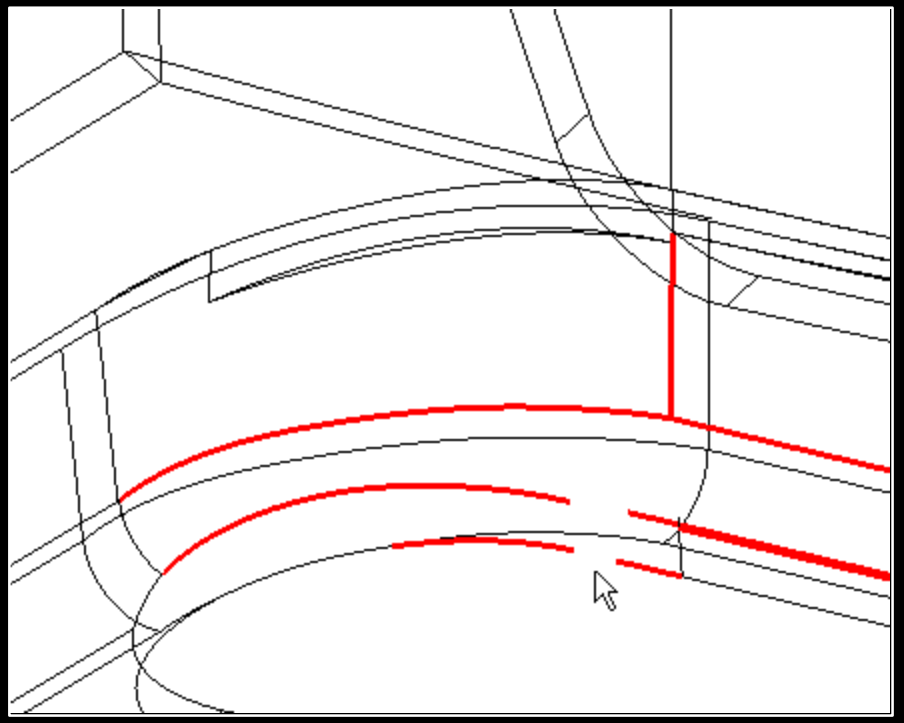
This is a single solid with two distinct internal volumes separated by a partition. The highlighted edges are each used to trim three faces--two outside faces and one interior face (with hole in it).

Most Common Accuracy Problems

- Large edge gap
- Large vertex gap

Poor Accuracy Example: Large Vertex Gap



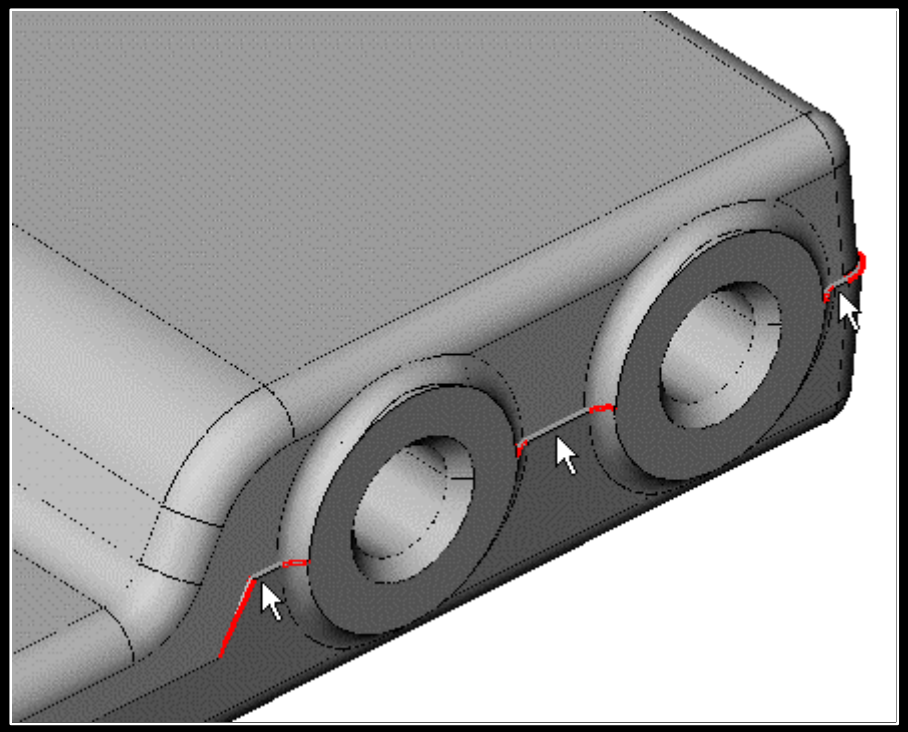


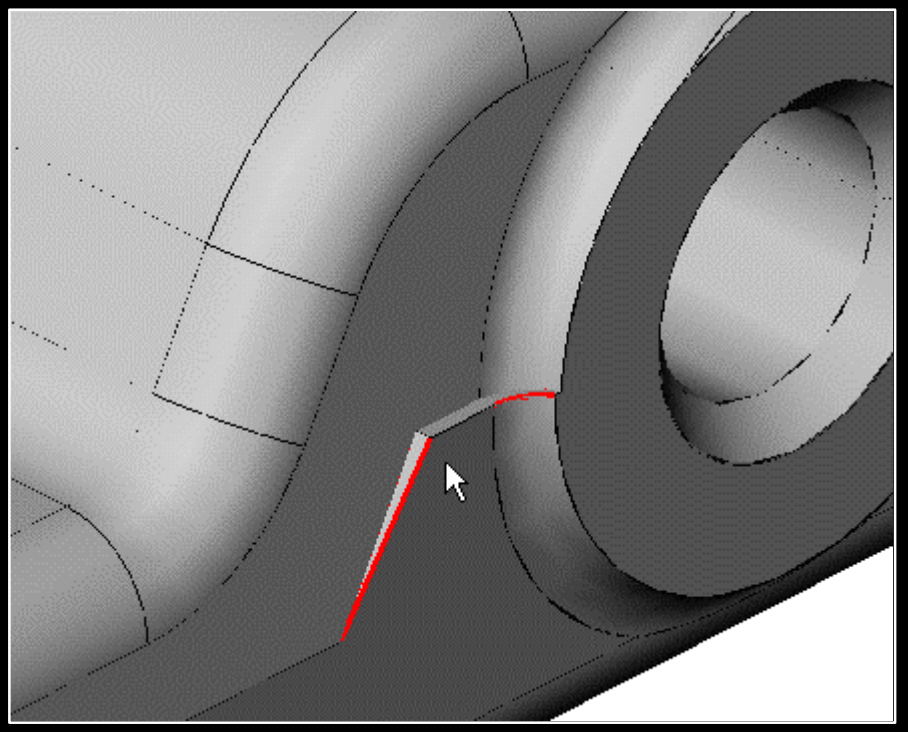
Surfaces from an industrial design system were imported then stitched together to form this solid. All of these highlighted edges are connected at a single vertex. The gaps are as large as 2.02 mm.

Most Common Realism Problems

- Short edge
- Small face
- Small edge curvature
- Sharp edge angle
- Sharp face angle
- Non-tangent edge and face angles
- Narrow region
- Narrow step

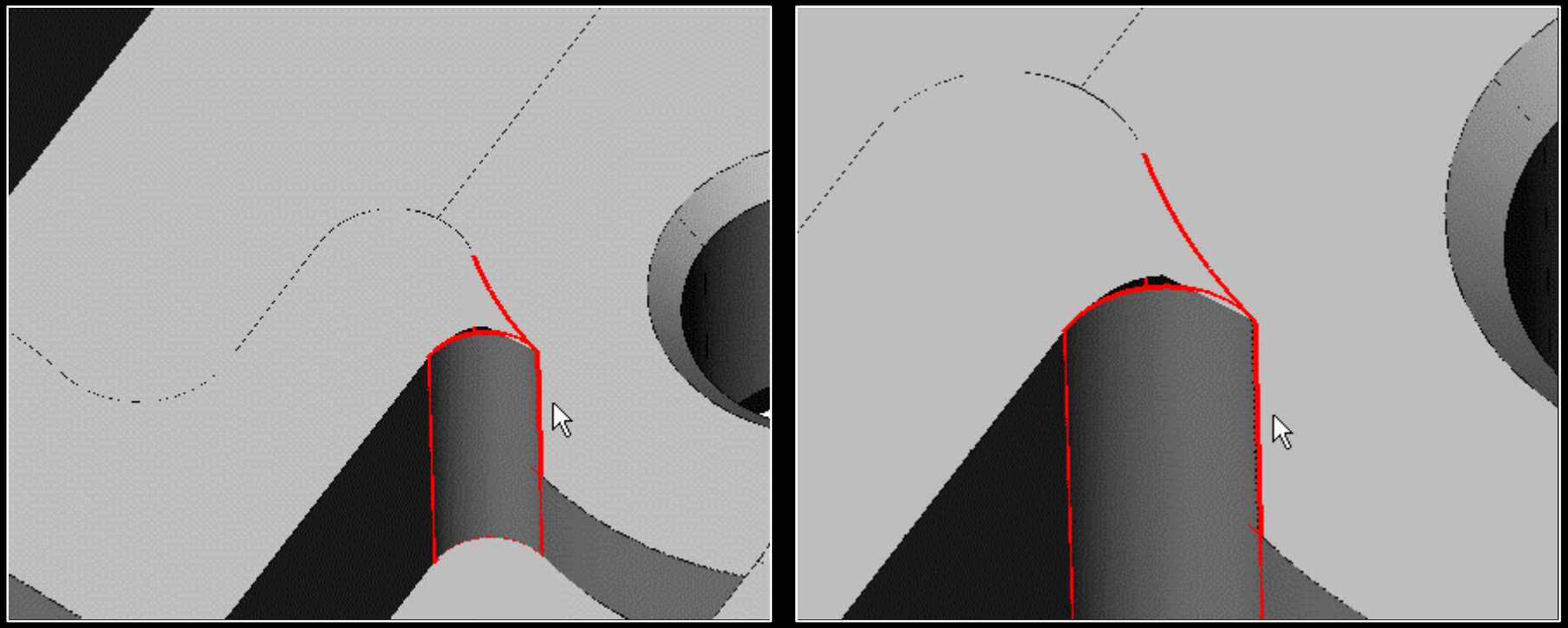
Unrealistic Geometry Example: Narrow Step





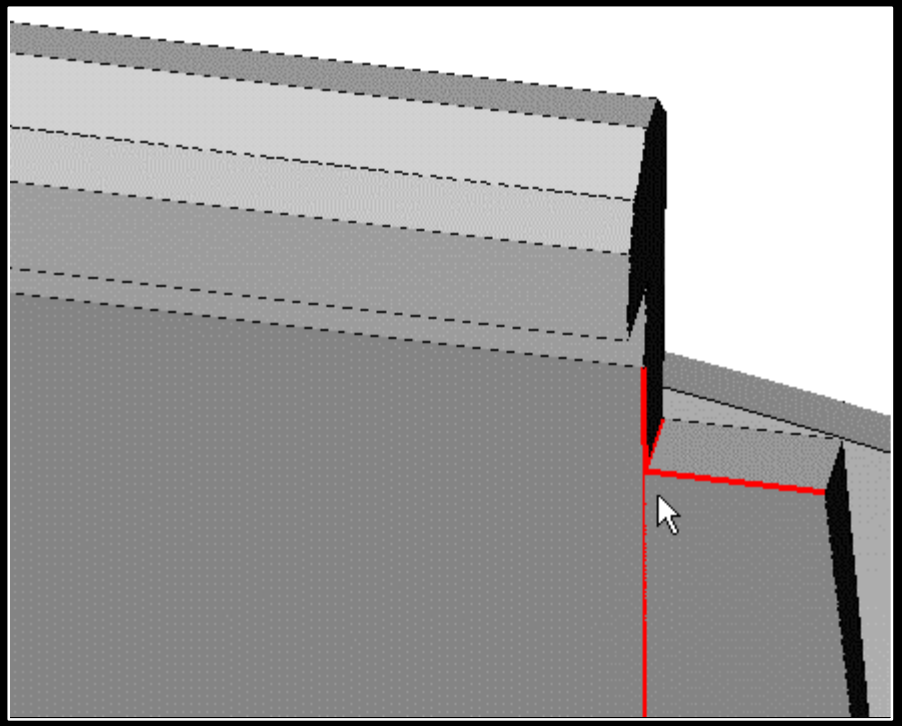
This casting has bi-directional draft angles defined from the top and bottom. They do not precisely match along the parting line. The highlighted micro-steps vary in width up to 1.0 mm.

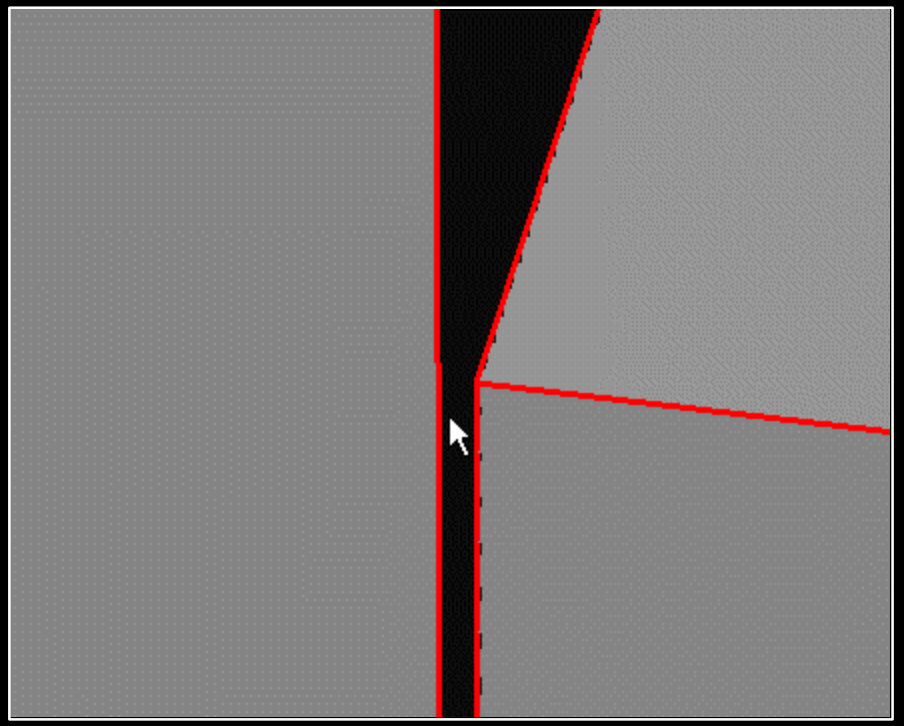
Unrealistic Geometry Example: Knife-Edge



This fillet is defined as part of the profile of the protrusion feature on the left. Because this protrusion extends higher than the boss on the right, a razor-sharp knife edge is created.

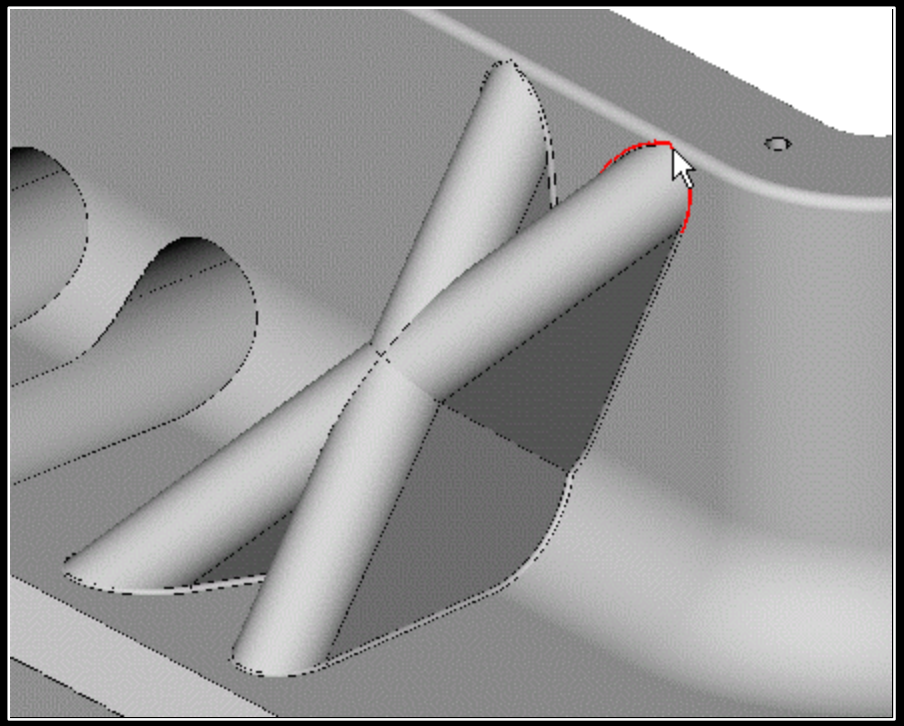
Unrealistic Geometry Example: Crack

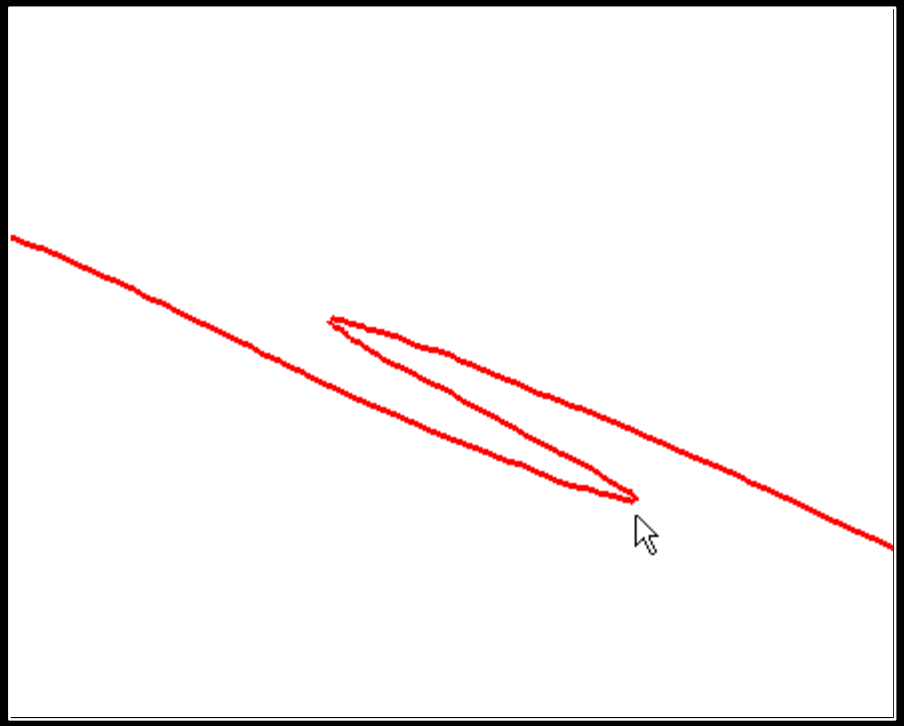




The narrow part of this tab on the right end is not connected. There is a 0.005 mm wide crack along the indicated line. This problem caused a rapid prototyping build process to fail along this line.

Unreal. Geometry Example: Rippled Edge



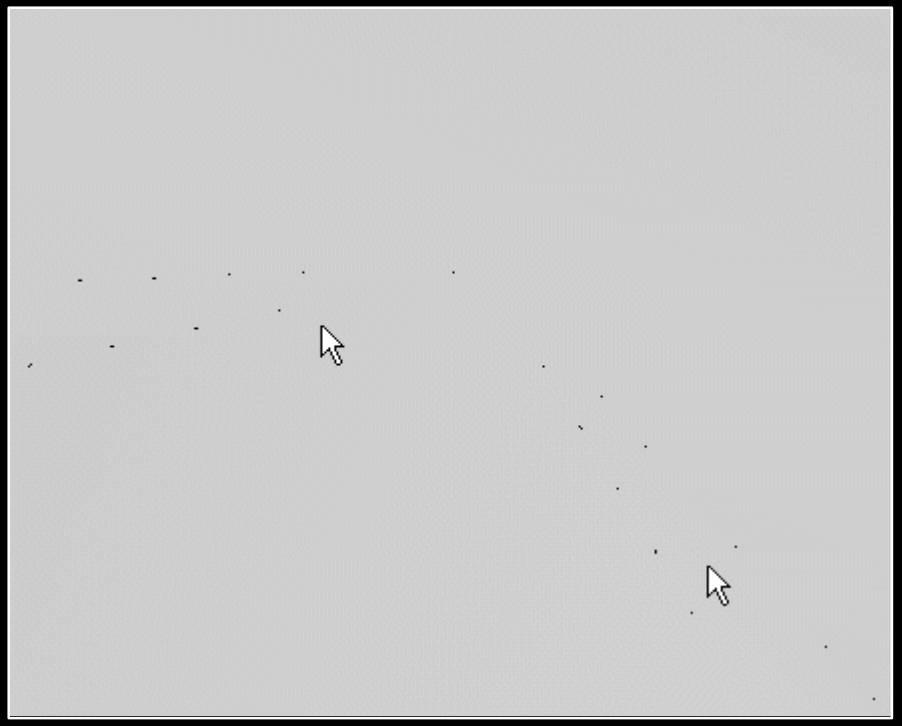


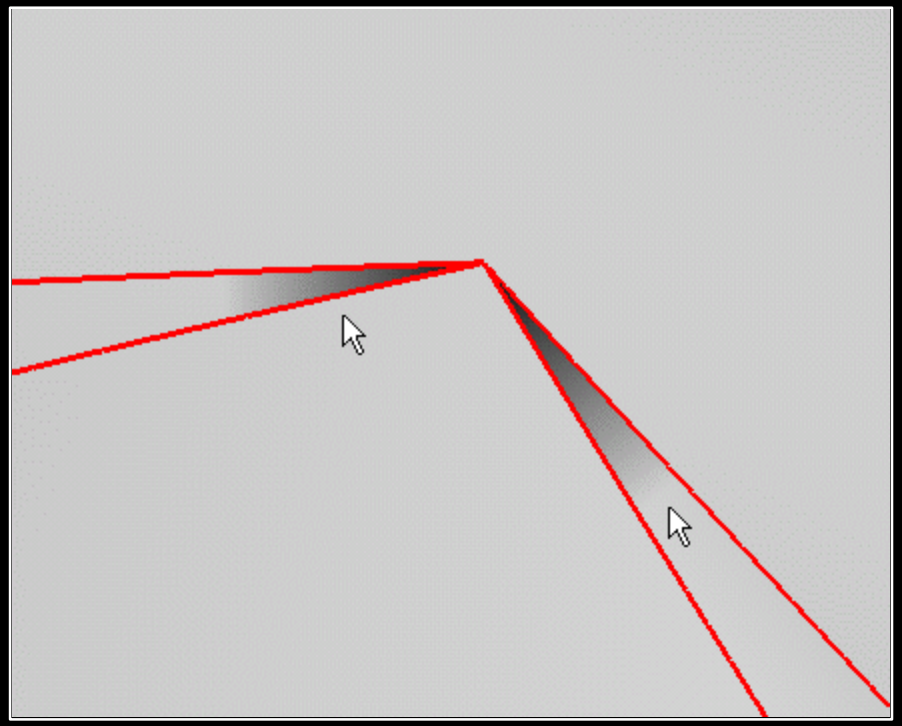
The outer fillet edge at the top of this feature doubles back on itself. The local radius of curvature is 0.00037 mm.

How STEP Impacts Model Quality

- Minor topology changes
- Some gaps get larger; others get smaller
- Some faces get curled, others get smoothed
- Most unrealistic feature interactions flow through unchanged
- Often the first downstream symptom of poor model quality

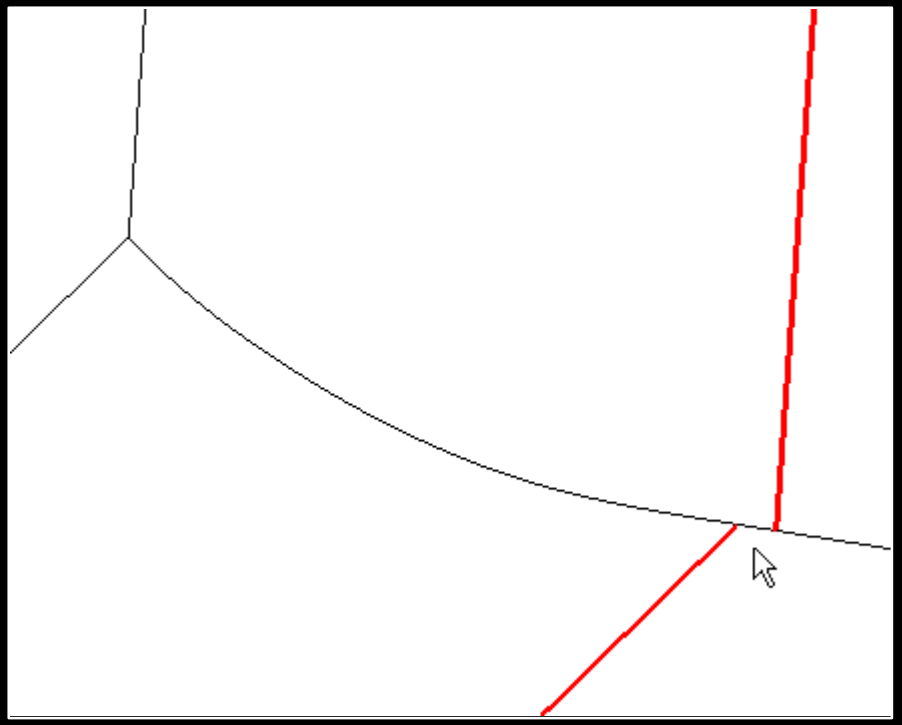
STEP Impact Example: New Curled Faces

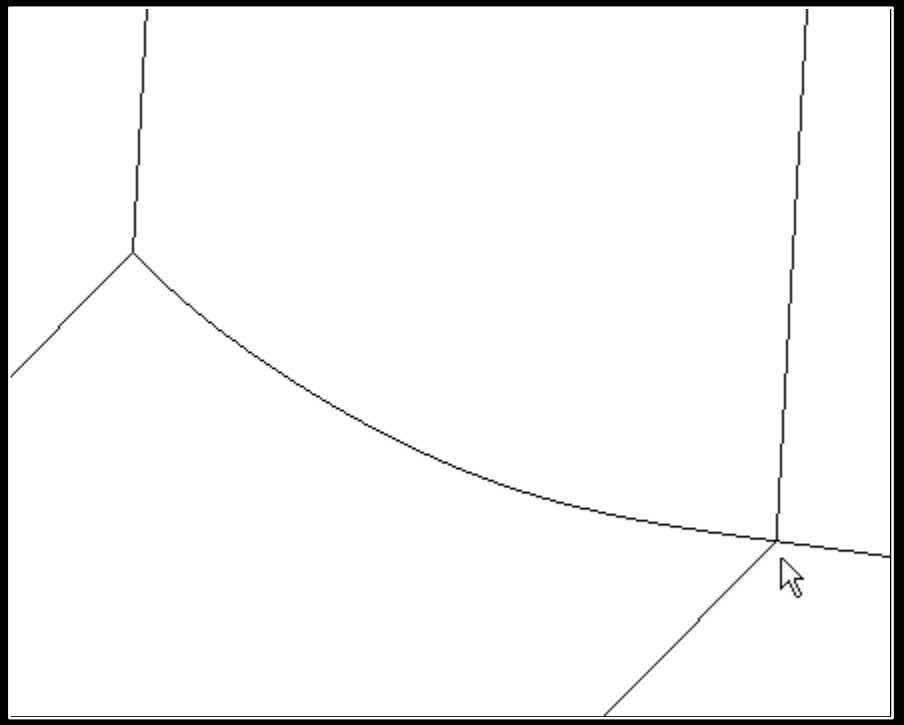




These blend (procedural) faces are smooth in the native model but are curled up at their acute corners in STEP. At their common vertex they form angles of 127 deg with the surrounding faces.

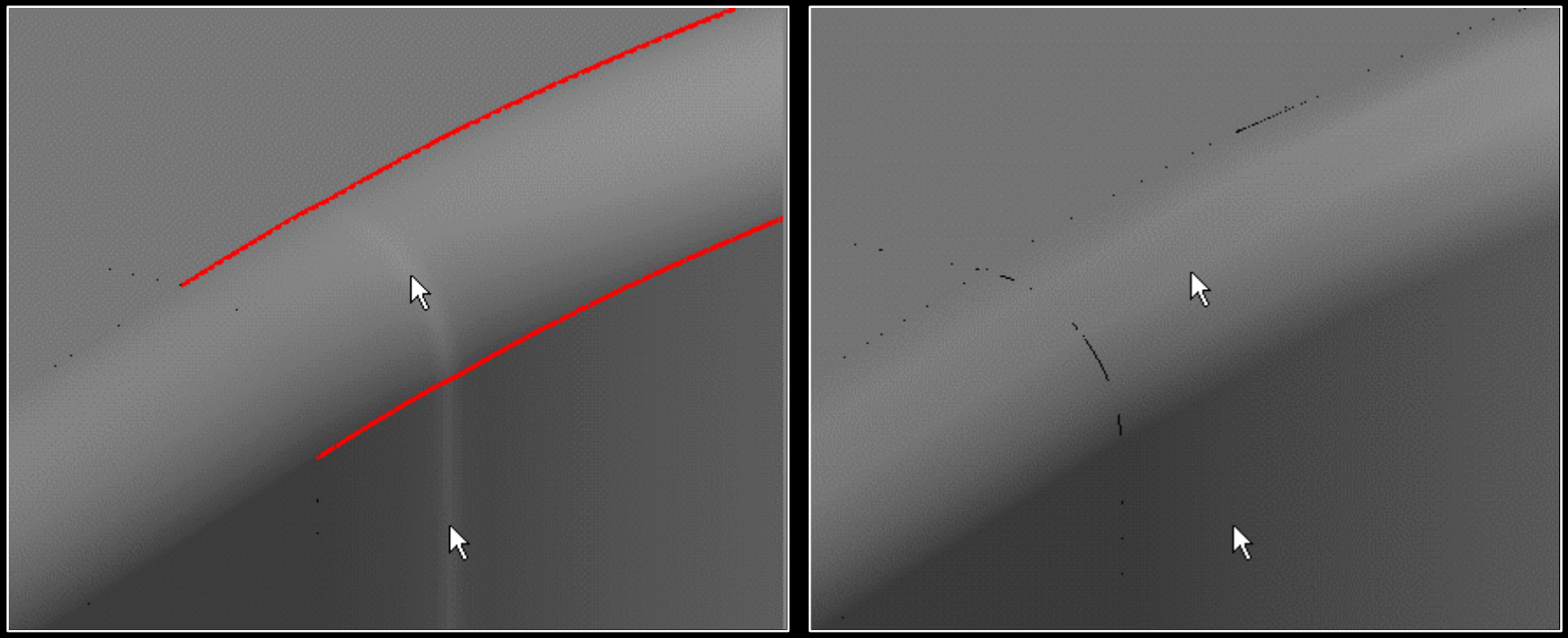
STEP Impact Example: Smaller Vertex Gap





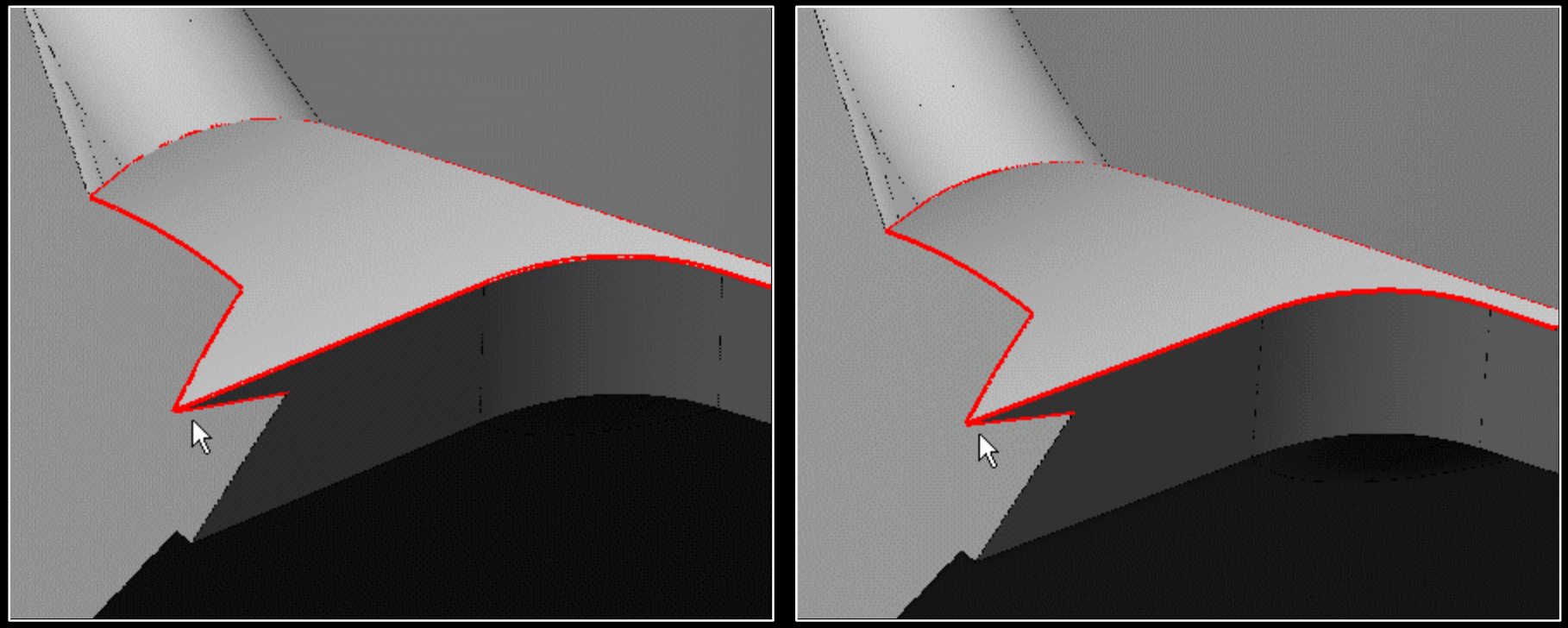
In the native model, the two edges along the right side of this fillet do not meet precisely. They have a gap of 0.02 mm between their endpoints. This gap was closed up during export to STEP.

STEP Impact Example: Smoothed Faces



The two native faces have a ripple (light shaded band indicated by arrows). Where this crosses the highlighted edges, the local radius of curvature is 0.067 mm. The faces are smooth in STEP.

STEP Impact Example: Unchanged Narrow Step and Knife-Edge



The blends and fillets in this region are slightly offset from each other. A 0.4 mm narrow step flares out on the left end to a sharp point in both the native and STEP models.

How Poor Model Quality Impacts STEP for Long-term Data Retention

- Incorrect structure ("show-stopper"): Undermines support for standards-based long-term data retention
- Low accuracy: Become "sleeper" problems since symptoms raise on import to target modeler
- Unrealistic geometry: More difficult to resolve as native modeler is not available

Value of High-Quality Models for STEP

- Demonstrate production-worthiness of STEP technology
- Focus efforts on process issues and product quality rather than CAD model quality
- Incorporate consistent model quality standards across extended enterprise
- Build confidence in acceptance of non-native models (partners, suppliers)
- Enable long-term STEP data retention

Recommended Model Quality Standard for STEP

- No structure problems (incorrect topology and voids)
- No large gaps (> 0.02 mm)
- No degenerate edges (length < 0.02 mm)
- No degenerate faces (area <= 0.0 mm^2)
- No self-intersecting face bounds (nar. reg. < 0.02 mm)
- No rippled edges (radius of curvature < 0.001 mm)
- No narrow steps
- No knife edges or cracks

Sources of Poor Model Quality

- Poor modeling technique
  - Novice designers
  - Expert designers switching CAD systems, modeling paradigms, or product domains
- Old models
  - Single-precision legacy data
  - Models migrated through several modeler versions
- Outdated modeling technique
  - Building solids by sewing surfaces
  - Explicit solid modeling

Sources of Poor Model Quality (cont)

- Intense modeling
  - Any designer making significant, last-minute changes
  - Major design intent changes
  - Repeated parametric changes
  - Stylized surfaces sewn together with “tolerant modeling”
- Automated models
  - Parameter-based model creation scripts (little designer review)
  - Envelope or “shrink wrap” models
  - Optimized models

Resolving Model Quality Problems

- All options based on efficient identification of significant problems (model quality testing software)
- Recommended problem resolution order
  - Structure
  - Realism
  - Accuracy
- Why realism before accuracy?
  - Many include accuracy problems
  - Prevent model regeneration at higher accuracy

Resolving Model Quality Problems (cont)

- Immediate options (no access to native modeler)
  - Repair target model
  - Rebuild target model
  - Try IGES or direct translators
  - Use CAD repair tool to improve STEP data quality then re-import into target system
- Short-term options (native modeler access)
  - Suppress features
  - Cut or consume features with Boolean operations
  - Regenerate model at higher accuracy

Resolving Model Quality Problems (cont)

- Short-term options (native designer access)
  - Rebuild features
  - Rebuild model
  - Redefine features to simplify topology
  - Adjust parameters to simplify topology
- Long-term options (product/process changes)
  - CAD modeler bug reports
  - STEP translator bug reports
  - Modeling technique standards and tools
  - **Model quality standards and feedback during model creation and modification**

Modeling Conventions and Model Quality

- Good if…
  - Simple
  - Enforceable
  - General
- Bad if…
  - Complex
  - Abstract
  - Too many exceptions or special cases
- Combine with model quality standards to engender designers who are craftsmen, not robots
- Remember: any model can be “pushed over the edge”

ITI Software Products for STEP

- AP 203 and 214 geometry translators
  - I-DEAS, Mechanical Desktop, CADDS5, Microcadam
  - Contact CAD vendors for version availability
- AP 203 PDM translators
  - Sherpa, Metaphase, Matrix One
  - Contact ITI for version availability
- AP 210 translator (ECAD to MCAD)
  - Developed in close cooperation with Boeing
  - First version in final beta testing

ITI Software Products for STEP

- CAD/IQ: Identifies model quality problems
  - STEP, CATIA, I-DEAS, Pro/E, Parasolid
  - Version 3.0 in beta testing
  - www.cadiq.com
- CADfix: Repairs moderate model quality problems
  - STEP, IGES, Parasolid, ACIS, CADDS5
  - Version 3.0 just released
  - www.cadfix.com
- CADScript: Multi-CAD programming interface
  - STEP, CATIA, I-DEAS, Pro/E, Parasolid
  - Version 1.0 in beta testing

Conclusion

High-quality CAD models enable successful production STEP exchange, effective downstream use of the model, and long-term product data retention.